Proceedings of the 7th Asia Pacific Conference on Industrial Engineering and Operations Management
Bangkok, Thailand, March 25-27, 2026

Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/AP07.20260284
Published: March 25, 2026

Reducing Defects through the Application of DMAIC, Six Sigma Methodology in a Tissue Converting Company in Tanauan City, Batangas

Aia Marie C. Basto, Chen Raleen R. Parra, Aeron Noel C. Salido and John Michael G. Mendoza
Industrial Engineering Department, First Asia Institute of Technology and Humanities,
Pres JP. Laurel Highway, Tanauan, 4232 Batangas, Philippines
aiacaballedabasto@gmail.com, cp02141112@gmail.com, noel.aeron12@gmail.com,
johnmichaelmendoza118@gmail.com

Abstract

Under the Six Sigma framework, this study implements the DMAIC (Define–Measure–Analyze–Improve–Control) methodology to methodically mitigate defects in a tissue manufacturing process. Process variability, machine limitations, and operational inefficiencies are inherent factors that contribute to quality deviations and elevated production costs in manufacturing systems. The primary goal of this research is to quantitatively assess the performance of the process and to implement engineering-based interventions that will reduce the occurrence of defects and improve operational efficiency. Based on the baseline analysis, the average defect rate per production cycle was 3.0% to 5.0%, which amounts to an estimated monthly loss of ₱94,000 to ₱157,000. Process mapping, Pareto analysis, and statistical tools were implemented to quantify critical performance indicators, including productivity rate, defect frequency, and process stability. The primary contributors to deterioration were identified as machine-related factors and process inconsistencies through root cause analysis. Mechanical modification and process optimization of the rewinding system were employed to implement engineering enhancements. The results of the post-implementation phase indicated a decrease in the defect rate from 4.2% to 1.6%, which amounts to a 61.9% enhancement in quality performance. On the other hand, disposal costs decreased by approximately 38%, while productivity also increased. A statistically significant difference was observed between the pre- and post-implementation results ($p < 0.05$) according to the t-test used for statistical validation. The enhanced process stability and reduced variability were further confirmed by control charts. The results verify that the integration of DMAIC methodology with engineering analysis and statistical validation establishes an efficient framework for process optimization and defect reduction. The study underscores the importance of mechanical process enhancement and data-driven decision-making in the pursuit of sustainable quality improvement in manufacturing systems. The results provide a scalable model for operational excellence and continuous development in industrial production environments.

Keywords
DMAIC, defect, optimization, control, efficiency.

1. Introduction
In the contemporary global manufacturing market, operational efficiency and product quality are critical determinants of business sustainability and customer satisfaction. Maintaining standards becomes increasingly complex, particularly in fast-paced production environments where even minor inefficiencies can result in huge losses. These inefficiencies not only increase costs though also induce operator fatigue, which further impacts product quality and total output. As a result, incorporating data-driven decision-making enables companies to identify root causes of

inefficiencies and prioritize improvements based on quantifiable impact, a principle embedded in Lean Six Sigma methodologies.

Among the various types of production waste, defects are considered one of the most critical, not only leading to material losses but also requiring additional time, labor, and resources to correct (Astutik et al., 2022). Considering these factors, application of DMAIC phases– Define, Measure, Analyze, Improve, and Control– where errors, defects, delays, extra-processing, and other wastes (DOWNTIME) or 8 Muda are eliminated through methodical steps. While other Six Sigma methodologies such as DMADV and IDOV are suitable for designing and developing new products or systems, the DMAIC methodology is most applicable to improvement projects that aim to reduce variation in existing processes, enhance performance, and optimize resource utilization (Al-Fadhli et al., 2022).

According to Liu et al. (2020), improving and ensuring the machine reliability and maintenance of Rewind Machines offers positive solutions to support growing demand and improve production efficiency in a tissue manufacturing industry. Coreless rewinding systems are equipment that rewinds tissue paper without the use of cardboard core and are designed with tension control, web guiding, and automated roll formation features.

The converting company focuses on producing tissues and table napkins, while operating in morning and night shifts, having a total of 24 hours a day from Mondays to Saturdays. Among their nearly daily production, they have an average 3% to 5% rate of defects among each production run. When converted, the given percentage data is equivalent to an estimated cost of ₱94,348.08 to ₱157,248.00 in a month. These defects are considered spoilage, described as unrefined tissue trimmings. Other wastes include crumpled tissues and torn tissue rolls, and the company's approach to handling the spoilage is to compress the scraps into a compact cube to be sold to other clients at a lower cost.

Furthermore, through a pre-assessment survey for both operators and customers, results were gathered to provide insights. Moreover, customers that use their products report that the quality of the tissue products is great and reliable to buy and use. On the contrary, some find minimal tissues that are crumpled or torn.

1.1. Objectives

This study focuses on applying the DMAIC methodology to evaluate production processes and facilities as well as to reduce defects, identifying and addressing key challenges impacting operational efficiency and contributing to waste occurrences. Specifically, it intends to explore and address the following objectives: (1) To define the current situation and key operational issues encountered by the incorporation by assessing the existing process through: 1.1 Process Mapping; 1.2 Pre-Assessment Survey; (2) To measure the performance of production processes and outputs of the incorporation in terms of: 2.1 Productivity Rate; 2.2 Production Costs; 2.3 Occurrences of various types of defects for prioritization using Pareto Chart; (3) To analyze the root causes of the identified problem using: 3.1 Cause and Effect Diagram; 3.2 Why-Why Analysis; (4) To improve existing production process by integrating an adjustable roll stopper in a tissue rewinding machine to streamline operation and reduce spoilage through the execution of short-term implementation and pilot testing aiming: 4.1 Decrease in Defect Rate; 4.2 Process Improvement and Efficiency; 4.3 Reduce in Disposal Cost; (5) To control the effectiveness of the proposed solution and improvements in reducing defects through: 5.1 Assessing the prototype in terms of functionality, effectiveness, and efficiency; 5.2 T-test for determining and comparing the difference between pre-assessment and post-assessment; 5.3 Utilizing Control Chart to monitor changes in amount of wastes; 5.4 Applying Control Plan to outline the actions performed to ensure that improvements were sustained, process is in control, and defects were reduced.

2. Methods

2.1 Research Design

The study made use of mixed-methods research design which involves both quantitative and qualitative designs. Particularly, the study employed Quasi-Experimental Design and Descriptive Design, that is suitable for pre-assessment and post-assessment to distinguish changes and improvements from the beginning to the end.

2.2 Subject of the Study

The employees of the company are the focus of the study, and employed a stratified random sampling approach, wherein the respondents were chosen based on their classifications such as employees or customers. Through Raosoft, the appropriate sample size was determined to be 108 employees, which was set to a 90% confidence level and a 5% margin of error.

2.3 Data Gathering Instrument
The researchers evaluated several business elements and performed a preliminary review of the production activities through the following data instruments: Raosoft, Survey Questionnaires, Semi-Structured Interviews, Microsoft Excel, Video and Image documentation. In addition, the following Quality Control Tools are used to better measure the data; Process Mapping, Pareto Chart, Cause and Effect Diagram, Control Charts, and Control Plans.

2.4 Data Gathering Procedure
Once the letters for approval of partnership have been noticed and approved, the researchers were permitted to conduct data collection to workers and selected customers a pre-assessment survey during breaks. Subsequently, observations will be conducted inside the production facilities to identify problems or inefficiencies, combined with interviews and recorded by notes, digital records, Excel, and documentation through photography and videos.

2.5 Data Analysis
The analyzation methods used in interpreting and examining the data of the study are the following: Sample Size Calculation, Weighted Mean, Likert Scale, Content Analysis, Visual Analysis, Document Review, Pareto Analysis, Why-Why Analysis, Comparison of pre-assessment and post-assessment using T-Test, and Statistical Process Control.

3. Results and Discussion
This study includes defining the current situation and existing process, measuring production processes and outputs, analyzing root causes of the problem, improving the current process with the proposed solution for spoilage reduction, and controlling the effectiveness of the solution or improvement.

1. To define the current situation and key operational issues encountered by the incorporation by assessing the existing process through:
1.1 Process Mapping
Figure 1 displays the process map for a coreless rewind machine, identifying a streamlined workflow starting with unwinding of parent rolls and ending with the rolling sheets, cutting, inspection, and packaging. However, there have been recurring issues in the "Unwinding, Rewinding and Rolling Tissue Logs" section.

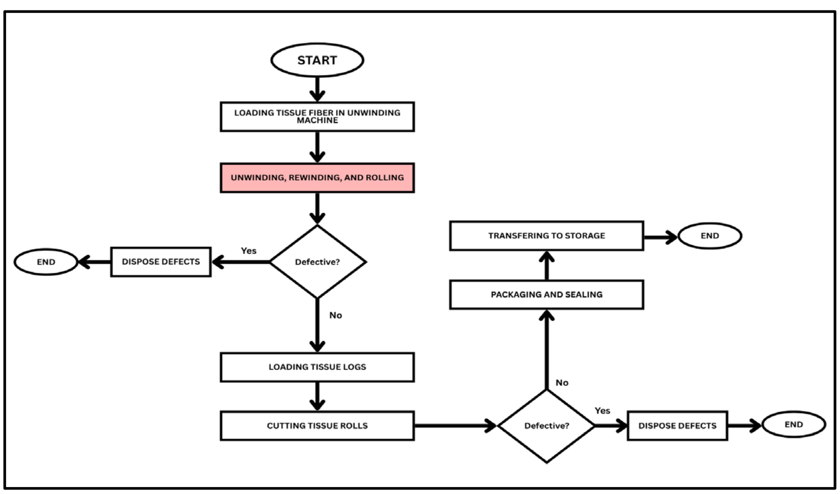


Figure 1. Process Mapping

1.2 Pre-Assessment Survey
The result of the pre-assessment survey indicated perspectives from both the operators and customers, detailing the current state of the tissue production process and the quality of the final product.

Table 1. Operator’s Quality Control Pre-Assessment Survey

Respondents	Level of Agreement	Response Rate (%)
Operator	Lubos na Sumasang-ayon (Strongly Agree)	0
	Sumasang-ayon (Agree)	88.5
	Hindi Sumasang-ayon (Disagree)	11.5
	Lubos na Hindi Sumasang-ayon (Strongly Disagree)	0

Table 1 indicates that 88.5% of operators agree (Sumasang-ayon) that they still face defects and excessive spoilage in production handling, while 11.5% disagree (Hindi Sumasang-ayon). These findings suggest clear opportunities for making operational process improvements to reduce inefficiencies and enhance the product quality.

Table 2. Customer’s Product Experience Pre-Assessment Survey

Respondents	Level of Agreement	Response Rate (%)
Customer	Lubos na Sumasang-ayon (Strongly Agree)	0
	Sumasang-ayon (Agree)	68.2
	Hindi Sumasang-ayon (Disagree)	31.8
	Lubos na Hindi Sumasang-ayon (Strongly Disagree)	0

Table 2 presents 68.2% of customers Agree (Sumasang-ayon) that the tissue products they purchased as generally reliable and of good quality. However, 31.8% disagreed (Hindi Sumasang-ayon), indicating crumpled or torn tissues which emphasized more quality control in manufacturing and packaging.

2. To measure the performance of production processes and outputs of the incorporation in terms of:

2.1 Productivity Rate

The researchers gathered the number of outputs that the company produces in 14 days, specifically in the coreless rewinding machine.

Table 3. Production Output from September 1, 2025, to September 14, 2025

Days	Outputs per Piece (Before)	Days	Outputs per Piece (Before)
1	145	8	326
2	236	9	238
3	218	10	269
4	263	11	281
5	284	12	279
6	67	13	2
7	47	14	0
Total			
2,655			

Table 3 shows the total output being produced each day in two weeks, from the first to second week of September 2025. The highest number of outputs produced was on the 8th day, with a total of 326 pieces of output. Meanwhile, the lowest number of outputs produced was on the 14th day wherein no operations were conducted, leading to zero (0) outputs, since Day 14 is Sunday, which is the allotted day for maintenance or repair activities. The company produced a total of 2,655 coreless tissues in the first two weeks of September prior to the implementation.

Productivity Formula

Productivity $= \frac{Total\ Output}{Total\ Input}$, Pre-implementation = $\frac{2{,}655\ units}{98\ hours} = 27.09$ units/hr

Upon obtaining productivity using the formula, the company can produce approximately 27.09 units per hour.

2.2 Production Costs

The researchers gathered the available data from the company to compute the estimated production cost per day from the first week to second week of September 2025. The price of the virgin pulp that serves as the primary material and the material cost to produce coreless tissues is equivalent to Php 28.00 per kilogram.

Table 4. Production Cost

Days	Outputs (Pieces)	Pulp used in kg	Response Rate (%)
1	145	21.75	609.00
2	236	35.40	991.20
3	218	32.70	915.60
4	263	39.45	1,104.60
5	284	42.60	1.192.80
6	67	10.05	281.40
7	47	7.05	197.40
8	326	48.90	1.369.20
9	238	35.70	999.60
10	269	40.35	1,129.80
11	281	42.15	1,180.20
12	269	41.85	1,172.00
13	2	0.30	8.40
14	0	0.00	0.00
Total	**2,645**	**439.85**	**12,315.80**

Table 4 exhibits the representation of the amount of tissue pulp used in kilograms from the span of 14 days, with an estimated total production cost of Php 12,315.80 with 2,655 outputs produced.

2.3 Occurrences of various types of defects for prioritization using Pareto Chart

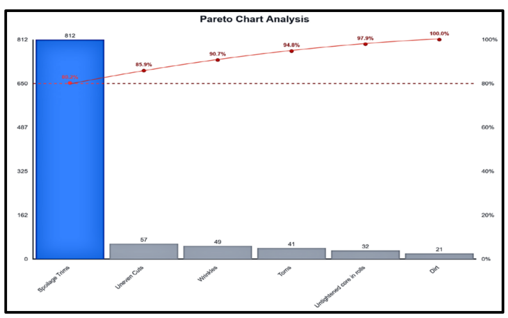


Figure 2. Pareto Chart

Figure 2 shows that the spoilage trims have the highest number of occurrences, with a total of 812. The spoilage trims build up 80.2%, which suggests that the spoilage trims are the main problem regarding defects and the type of defect that must be prioritized to solve and improve.

3. To analyze the root causes of the identified problem using

3.1 Cause and Effect Diagram

The cause-and-effect diagram or fishbone diagram was used to state all potential causes of the issue to spoilage.

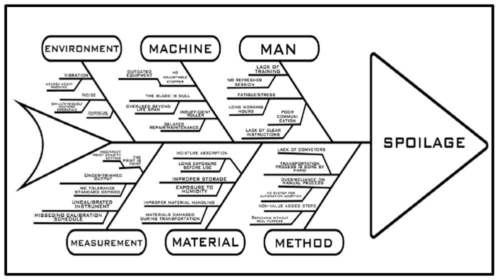


Figure 3. Ishikawa Diagram

Figure 3 shows the fishbone diagram that displays the potential root causes of the problem, specifically spoilage. The researchers considered the lack of an adjustable stopper at the ends of the machine and proposed a design as the solution to resolve the problem.

3.2 Why-Why Analysis

The researchers also conducted a Why-Why Analysis to find the primary root cause and strengthen the analysis in determining possible factors that result in spoilage through asking multiple questions of “why?”.

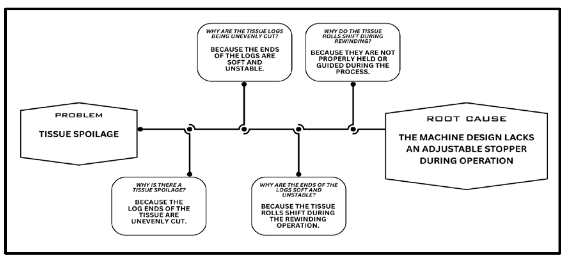


Figure 4. Why-Why Analysis

Figure 4 above depicts the why-why analysis which shows that spoilage occurs because the log ends of the tissue are unevenly cut, leading to unrefined ends. In line with this, the ends of the tissue logs are also soft and delicate, making it unstable. The researchers discovered that the design of the machine lacks an adjustable stopper that can stop and stabilize the tissue at each end of the tube.

4. To improve existing production process by integrating an adjustable roll stopper in a tissue rewinding machine to streamline operation and reduce spoilage

After identifying the problem and pointing out the root causes of spoilage, the researchers designed and developed an adjustable stopper at the ends of the tube attached in the coreless tissue rewinding machine (Figure 5).

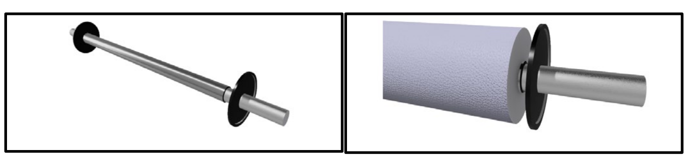


Figure 5. 3D Image

Figure 5 above illustrates the three-dimensional image of the adjustable stopper that serves as a solution to minimize spoilage count and smoothen the edges of the coreless tissue while undergoing the rewinding process. The product is attached to both ends of the tube in the rewinding machine and begins to function after the operator places the stopper into the ends of the tube before the rewinding process starts.

4.1 Decrease in Defect Rate

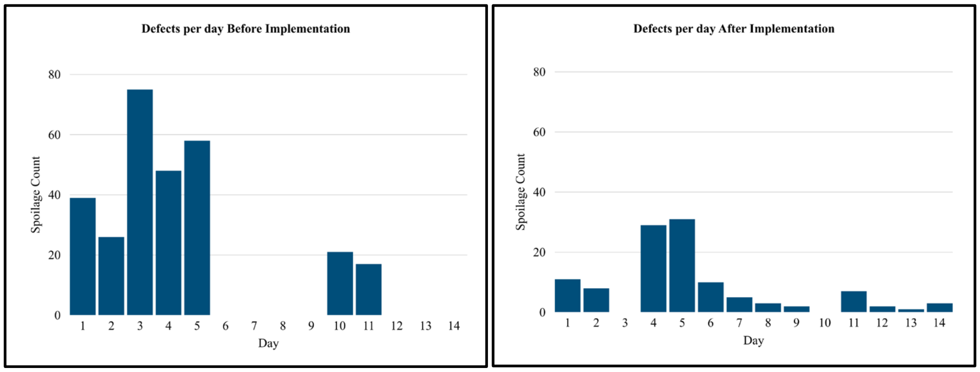


Figure 6. Defects per day Before and After Implementation

Figure 6 displays the number of defects per day before (left) and after (right) the implementation of the proposed solution. Before implementation, the 3rd day has the highest number of spoilages with a total amount of 75. On the other hand, after integrating an adjustable stopper at the ends of the tube attached on the tissue rewinding machine for another fourteen (14) days of implementation, the number of spoilages per day decreases. The highest number of defects became 31 after the prototype was applied in the process. The rate of change shows that the spoilage count was reduced by 60.56%, signifying that the implemented solution was effective in decreasing spoilage.

4.2 Process Improvement and Efficiency

Productivity Rate

The researchers also gathered data regarding the number of outputs produced during the 14 days of implementation to measure the productivity performance of the operation.

Table 5. Production Output from October 3, 2025, to October 16, 2025

Days	Outputs per Piece (Before)	Days	Outputs per Piece (Before)
1	231	8	237
2	241	9	244
3	0	10	0
4	233	11	249
5	243	12	236
6	229	13	247
7	231	14	230
Total			
2,851			

Table 5 above shows the collected data about the production output after the (14) days implementation with a total of 2,851 coreless tissues. The 11th day has the highest number of outputs with a total of 249 outputs, while the 3rd and 10th days have the lowest with zero (0) outputs due to various factors such as no operations, maintenance activities, or absence of operators.

Productivity Formula

Productivity = $\frac{Total\ Output}{Total\ Input}$, Pre-implementation = $\frac{2{,}851\ units}{98\ hours}$ = 29.09 units/hr

The data depicts that there is an increase in the productivity of the process after integrating the adjustable stopper in the machine; the productivity increases up to 29.09 units per hour.

Time Study

The time study provides an overview of operational efficiency before and after implementation to further validate if there would be a significant difference, in terms of time, in integrating the stopper.

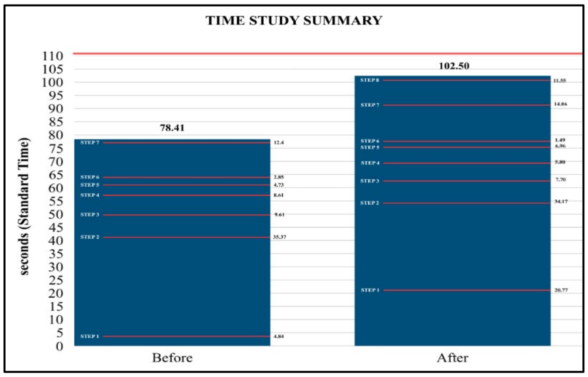


Figure 7. Time Study Summary

Figure 7 summarizes the Coreless Machine Time Study, with a total of 20 observations for pre-implementation (current process) and another 20 observations during the implementation of stopper. The red line indicates the computed standard time of 110.04 seconds. The total standard time derived from time study increased from 78.41 seconds to 102.50 seconds during the integration of the stopper. The observed standard time does not exceed the computed actual standard time, which signifies that the longer duration time does not affect efficiency.

Post Assessment

The post-assessment survey result reveals the viewpoints of both the operators and customers in terms of the improvement seen in the tissue production process and the quality of final products after the addition of stopper on the roller used.

Table 6. Operator's Quality Control Post-Assessment Survey

Respondents	Level of Agreement	Response Rate (%)
Operator	Lubos na Sumasang-ayon (Strongly Agree)	51.40
	Sumasang-ayon (Agree)	48.60
	Hindi Sumasang-ayon (Disagree)	0
	Lubos na Hindi Sumasang-ayon (Strongly Disagree)	0

Table 6 reveals that 51.40% of operators Strongly Agree (Lubos na Sumasang-ayon) and 48.60% Agree (Sumasang-ayon), that implementing the stopper in the production process improved their workflow. This demonstrated high confidence that the process has improved tissue roll alignment and consistency, despite adding another step in the process, contributing assurance in minimizing defects.

Table 7. Customer's Product Experience Post-Assessment Survey

Respondents	Level of Agreement	Response Rate (%)
Customer	Lubos na Sumasang-ayon (Strongly Agree)	88.90
	Sumasang-ayon (Agree)	11.02
	Hindi Sumasang-ayon (Disagree)	0
	Lubos na Hindi Sumasang-ayon (Strongly Disagree)	0

Table 7 shows that 88.98% of the customers Strongly Agree (Lubos na Sumasang-ayon) and 11.02% Agree (Sumasang-ayon) that the quality of the tissue rolls is better after the changes were made. This reflects a high level of positive regard for the product, indicating a smoother and more uniform roll.

4.3 Reduce in Disposal Cost

Prior implementation, Figure 8 shows the total disposal cost is Php 4,260 while after implementation the disposal cost is Php 1,680. The data signifies the effectiveness of the implementation in terms of reducing defects and cost, as well as improving performance output. The rate of change shows a 61% decrease in disposal cost.

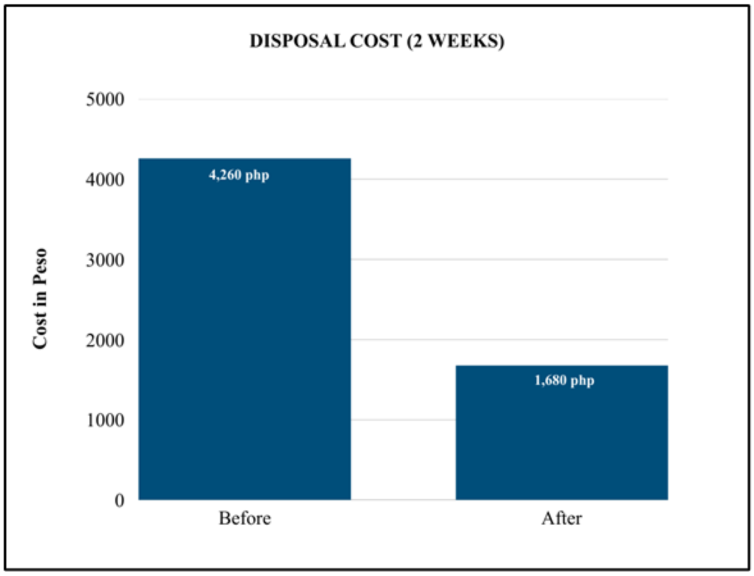


Figure 8. Disposal Cost Summary

5. To control the effectiveness of the proposed solution and improvements in reducing defects through:

5.1 Assessing the prototype in terms of functionality, effectiveness, and efficiency

Table 8. Assessment Overview in terms of Functionality, Effectiveness, and Efficiency

Criteria	Yes	No	Needs Improvement	Comments
A. Functionality				
1. The Stopper activates at the correct point of the rolling process to prevent misalignment.	/			Minor calibration for smoother response
2. The system or mechanism of the stopper is reliable during continuous operation.	/			Operates reliably
3. The prototype integrates properly with existing systems or processes.	/			Acceptable integration with slight adjustments for alignment
B. Effectiveness				
1. The Stopper effectively reduces defects such as uneven winding, wrinkles, or excess roll length.	/			Noticeable reduction in spoilage
2. Output quality shows noticeable improvement after implementation	/			Improved output consistency; minor issues at high speeds
3. The prototype contributes to achieving consistent product dimensions and uniformity.	/			Achieved better roll and stability
C. Efficiency				
1. The Stopper decreases cycle time by maintaining a smooth and controlled flow of tissue rolls.			/	Slight time increase due to added stopper removal/installation step
2. Energy and material waste are reduced due to more accurate stoppage control.	/			Waste reduced and energy consumption remains consistent
3. Maintenance requirements are minimal, and the mechanism is easy to clean or adjust.			/	Needs improvement in insertion of stopper in secondary roller

Table 8 displays the assessment of the product in terms of its functionality (A), effectiveness (B), and efficiency (C). Wherein, in terms of functionality (A), the stopper is functioning as intended to prevent tissue misalignment and demonstrating the same functionality; in terms of effectiveness (B), the integration of stopper adopted well to the existing process of coreless with slight modification specifically during stops and starts; lastly, in terms of efficiency, the stopper improved accuracy and reduced defects, it slightly extended the overall cycle through with the added step of removing and reinstalling of the stopper.

5.2 T-test for determining and comparing the difference between pre-assessment and post-assessment

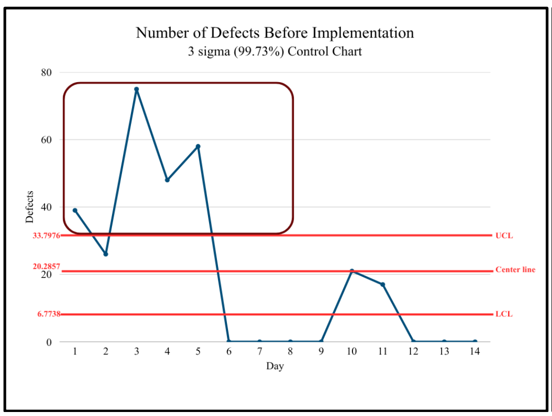
The researchers utilized Paired Sample T-Test using the two sets of data gathered before and after the implementation to determine if the proposed solution brought a significant improvement in reducing spoilage. T-test can assure if the difference is only by a random chance or indeed has a real causation that must be addressed.

Table 9. T-test Summary

Statistics	Value
Number of Samples	14
Mean Difference	12.29
Standard Deviation Difference	13.59
SE Mean Difference	3.64
t-value	2.07
p-value	$\approx$ **0.058**
Degrees of Freedom	13
tcritical	1.771
Decision	Reject Null Hypothesis
Conclusion	Number of spoilage decreased after implementation of the solution

Table 9 presents the summary of the T-test conducted in determining the significant difference between two sets of data. Since a one-tailed test was used and the degrees of freedom is 13, the critical t-value is 1.77. Furthermore, the computed t-value is 2.07. Since the computed value is greater than the critical value, the null hypothesis shall be rejected. Therefore, there is a significant reduction in the number of spoilage after the implementation of the proposed solution. The prototype that served as a solution brought improvements in decreasing the spoilage count.

5.3 Utilizing Control Chart to monitor changes in amount of wastes



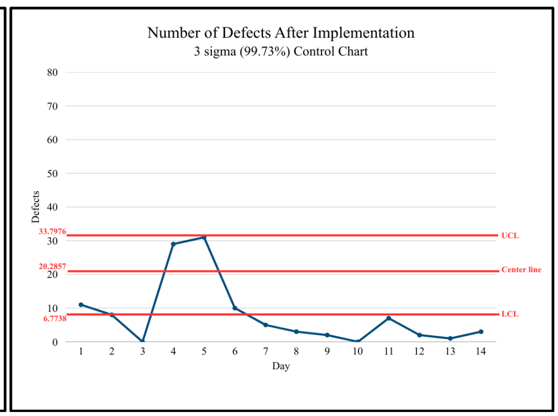


Figure 9. Control Chart Before and After the Implementation

Figure 9 depicts some data points that go beyond the upper control limit which indicates variation and the number of defects for the said sample is unusually high. The spoilage counts before (left), starting from days 1, 3, 4, and 5 are higher than the normal or expected count of defects, which means there is a presence of special cause variation. The data proves that the increase in the number of spoilage trims is indeed caused by a certain problem that needs to be identified and solved. Conversely, the number of spoilages was reduced after (right) the proposed solution was applied. The data points were within the control limits, and some exceed the lower limit, which signifies improvement and reduction of spoilage. The data indicates that the new recorded number of defects are acceptable and within control.

5.4 Applying Control Plan to outline the actions performed to ensure that improvements were sustained, process is in control, and defects were reduced

The application of a control plan ensures that the control actions are planned, and evaluation methods are used to ensure that the improvements stay as consistent as possible, highlighting a step-by-step process and individually adding any specifications or tolerance when it comes to performing the operations.

Prototype	✓	Pre-Launch		Production		Key Contact/Phone	Date (orig.)	Date (rev.)
Control Plan No. 1						Work Order No. 1	Purchase Order No.	Other Ref.
Part Number/Latest Change Level						Core Team **Unwinding Team**	Customer Engineering Approval/Date	
Part Name/Description **Unwinding Machine**						Supplier/Plant Approval/Date	Customer Quality Approval/Date	
Supplier/Plant **SCPA**	Supplier Code					Other Approval/Date	Other Approval/Date	

Part/Process No.	Process Name/ Operation Description	Machine, Device, Jig, Tools for manufacture	Characteristics			Specific Characteristic Classification	Methods					Reaction Plan
			No.	Product	Process		Product/Process Specification/ Technique	Evaluation Measurement Technique	Sample		Control Method	
									Size	Freq.		
I	Loading of raw materials in unwinding machine	Crane and Unwinding Machine			Loading Materials		Loading Materials	No visible damage or tarnish on raw tissue fibers	1 Ton of Tissue Fibers	Every time the unwinding machine depleted of tissue fibers	Prepare another batch of tissue fiber nearly at the end of depletion	Always do planned maintenance on crane and check inventory for any damage.
II	Unwinding	Unwinding Machine and Stopper prototype		Rolled Tissue Logs	Product Processing		Product Processing Attach Stopper Arm properly to avoid it slipping off during operations	No tears or crumple visible. Both sides are uniformly even	• 7.62 cm in Height • 6 cm in Dimension • 3 cm in Radius • 18.84 in circumference	8 Seconds per Tissue Roll	Use Stopper Arm to Ensure quality output.	Train operators on how to use Stopper Arm to ensure proper performance and output
III	Glue seal tissue logs	Glue Bottle		Finished Tissue Logs	Product Processing		Product Processing	No tears or crumple visible.	• 7.62 cm in Height • 6 cm in Dimension • 3 cm in Radius • 18.84 in circumference	6 Seconds per Tissue Roll	Apply glue steadily to ensure even coat	Always have glue supply to ensure no delays
IV	Loading Tissue Logs in to log saw	Log Cart			Transportation		Transportation	Log Cart is full of quality tissue logs		Once Unwinding Machine has depleted raw materials	Make sure no environmental hazards are present to avoid accidents	Always clean Log Cart to avoid staining the product with dirt.
V	Cutting Tissue Logs in Log Saw	Log Saw		Finished Tissue Rolls	Product Processing		Product Processing	No dirt present in tissue. Both rear ends are clean cut	• 7.62 cm in Height • 6 cm in Dimension • 3 cm in Radius • 18.84 in circumference	10 Tissue Rolls per Tissue Log	10 Tissue Rolls per Tissue Log	Always do planned maintenance on Log Saw to ensure proper operation.

Figure 10. Control Plan

Figure 10 shows the control plan for the converting company to make sure that the rate of defects no longer reaches beyond the upper limit. However, spoilage still has the chance to occur due to various factors.

5. Summary of Findings, Conclusion, and Recommendations

This chapter presents the study's summary of findings before, during, and after the implementation.

5.1 Summary of Findings

(1) In the process of coreless tissue production, unwinding, rewinding, and rolling are the main value adding activities. 90% of the operators agree that changes and ideas need improvement. 32% of the customers find that product quality can be improved.
(2) The rate of production increased to 2,975. It costs Php 12,315.80 to produce 2,655 outputs. 80.2% of the defects that contribute to waste are spoilage trims based on the Pareto chart.
(3) The Ishikawa Diagram shows the issue is a machine-based problem and the Why-Why Analysis reveals that the machine's rolling process lacks support to stabilize during operations
(4) The defect rate is 56% decrease in spoilage (159 Defects Reduced) while the time study shows a new total standard time of 102.50 seconds (24.11 sec added) and the disposal cost was reduced by 54% decrease (Php 2,245).
(5) The stopper was able to work effectively with minimal to no calibration as proven with the T-test rejecting the Null Hypothesis and only 1 point of data exceeded the control limit. To further control and educate current and future operators about the changes and impact of the stopper, a stopper manual and training for operators to effectively use and maintain the stopper will be given.

5.2 Recommendation

Based on the findings and conclusions of the study, the researchers suggest the following recommendations for further improvements: (1) other types of defects such as uneven cuts, wrinkles, torn tissues, loose core, and dirt must also be addressed to totally eliminate wastes, optimize use of materials and resources, and minimize disposing due to defects or rejects; (2) replacing the current rewinding machine with a new, updated, and advanced machine with an attached stopper already installed since the current machine is outdated and needs calibration; (3) the design, structure, formation, or development of the stopper can be further improved in terms of materials, composition, and physical design. Additional technicalities as well as programming or coding can be added for an enhanced automation of the product; (4) suggest training operators and maintenance personnel through proper training about the correct usage and maintenance of the stopper as well as developing an easy to understand Standard Operating Procedures (SOP) for operators' guidance during the testing, utilization, or troubleshooting; (5) The company can also implement a monitoring and feedback system to monitor the defect rates regularly as well as to gather feedback from operators; (6) The adjustable stopper can be added to the standard production process of coreless tissue production.

References

Astutik, W., Setiawan, I., and Asmal, S., Analysis of continuous quality improvement using waste assessment model and Deming cycle method (study case: tapioca starch manufacturing), Journal of Industrial Engineering Management, 2022.

Al-Fadhli, A., Ismail, A. R., Che Haron, C. H., Ab Ghani, M. K., and Ariffin, M. K. A. M., Application of Lean Six Sigma methodology to improve the railcar bogie assembly process, Heliyon, vol. 8, no. 11, 2022.

Cayabyab, G., What is a manufacturing defect?, SafetyCulture, 2025.

Croft, D., Guide: Fishbone Diagram, Learn Lean Sigma, Mar. 12, 2024.

Frady, L., Determine the root cause: 5 whys, iSixSigma, Jan. 23, 2025.

Liu, X., Wang, H., and Zhang, Y., Design and analysis of a high-efficiency web winding system for coreless applications, Journal of Manufacturing Processes, vol. 56, 2020.

Micaot, Number of observations required in industrial time study, Cronometras: App de Cronometraje Industrial y Métodos y Tiempos, 2023.

SixSigma, Control Plan in Lean Six Sigma: Key Elements and Strategies, 6Sigma.us, 2024.

Tronier, R., Process Mapping Guide: Definition, How-To, & Examples, Asana, May 16, 2025.

Biographies

Aia Marie Basto is an Industrial Engineering student at FAITH Colleges with a strong foundation in process optimization and data-driven decision-making. She has developed skills in leadership, multimedia editing, and strategic problem-solving, and is confident in presenting complex ideas that foster teamwork and impactful presentations. Aia served as JPIIE–FAITH Chapter executive officer for two years and is currently an active member in the Society for Environmental Education and Development of FAITH. She holds certifications including Lean Six Sigma Yellow Belt, Safety Officer 2, and Certified Kaizen Professional. She has also participated in several leadership and professional development programs such as the 19th PIIE National Student Congress and PAPSAS 16th Interactive Youth Forum.

Chen Raleen Parra is an Industrial Engineering student at FAITH Colleges who is enthusiastic about critical thinking, decision-making, problem solving, and data analysis which are beneficial in maximizing resources, optimizing processes, streamlining workflows and operations, analyzing systems, and enriching the industry on the whole. She is equipped with knowledge about the significant concepts of Lean Six Sigma, Process Improvement and Optimization, Quality Management, Time and Motion Study, and Kaizen (Continuous Improvement). She is knowledgeable in applying basic quality control tools such as Pareto Chart, Ishikawa Diagram (Fishbone Diagram), Flowchart, and Check sheet which are useful in determining root causes and analyzing data to arrive at informed decisions and generate impactful solutions to solve quality-related problems. Chen also possessed skills such as leadership, adaptability, and proactiveness. She holds certifications including Project Management Fundamentals Certification (PMFC), Certified Lean Six Sigma Yellow Belt (CLSSYB), Safety Officer 2 (SO2), and Certified Kaizen Professional (CKP). She firmly believes in the essence of continuous learning to aim for growth and competency at a greater level.

Aeron Noel Salido is a student at FAITH Colleges with a bachelor's degree in industrial engineering. He has participated in a variety of competitions throughout his academic career. He holds a Lean Six Sigma Yellow Belt Certification, is a Safety Officer 2, and is a Certified Kaizen Professional. His research interests include optimization, chemistry-aligned topics, medical care, and machinery.

John Michael Mendoza is a Certified Industrial Engineer and a college instructor at FAITH Colleges, where he teaches Industrial Engineering courses that connect analytical methods with real operational challenges. His instruction emphasizes systems thinking, structured problem solving, and measurable improvement, preparing students to analyze workflows, set work standards, improve productivity, and strengthen quality performance. He integrates applied tools such as process mapping, work measurement, basic operations research, and statistical quality methods to help learners develop industry-ready competence and professional discipline. John is currently pursuing graduate studies at Lyceum of the Philippines University–Laguna (LPU-L) under the Master of Engineering in Industrial Engineering (MEngIE) program. He also serves as adviser of the JPIIE–FAITH Chapter, guiding student leaders and members through activities that foster technical growth, leadership formation, collaboration, and engagement with the wider Industrial Engineering community. Through education, mentorship, advocacy, and lifelong learning, he aims to develop future Industrial Engineers who are competent, ethically grounded, and prepared to contribute to efficient, quality-focused, and sustainable organizations.